Spatial Analysis Study for Site Specific Management in Arkansas, USA

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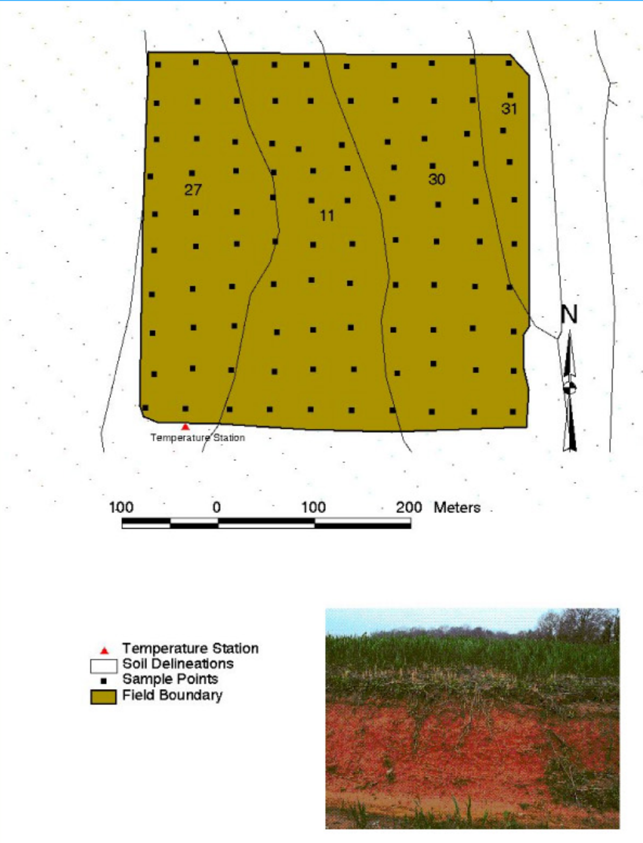

Figure 1. Delineation of soil boundaries in Field 1.

Abstract

Soil properties on two 16-ha fields were examined for spatial variability in Arkansas, USA. Ten surface properties and site features were first collected along a 100-point grid matrix, then interpolated using ArcView software. The results of each of these properties were then analyzed. It was concluded that all of these properties and site features have an interrelationship with the soybean crop yield. Due to laser leveling practices, the depth to redoximorphic mottling is conjectured to have the least impact on soybean yield.

Figure 2. Field 1 has been laser-leveled resulting in a flat landscape.

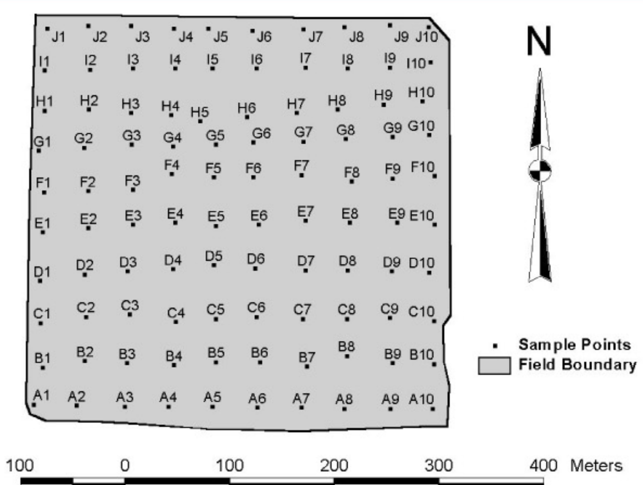

Figure 3. Sample points for Field 1.

Figure 4. All data were electronically recorded in the field using a GPS and a PC laptop.

Introduction and Purpose

Site specific management (SSM), despite lofty attempts for a precise definition, is simply doing the right thing in the right place at the right time. United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) soil survey maps are generally not used as a digital layer when it comes to site specific management decisions. In fact, some researchers in the SSM community feel that grid data composed of soil chemical properties constitutes a soil map. These chemical properties, requiring laboratory analysis, most commonly consist of organic matter, calcium, potassium, phosphorus, nitrogen, and soil pH.

Previous studies in Illinois, Iowa, and Missouri indicate that USDA-NRCS order 2 soil survey maps have somewhat limited value for SSM (Mount et al., 1998). Order 2 soil survey maps are at a scale of 1:15,840 or smaller whereas order 1 soil survey maps suitable for SSM decisions are at a scale of 1:8000 or larger. The map scale that separates order 1 and order 2 soil surveys is 1:12,000 (Soil Survey Staff, 1997).

The order 2 soil survey map of Lonoke County was examined prior to field activities. Four soil delineations are in Field 1 and one delineation covers all of Field 2 (Figure 1).

The process of completing an order 1 soil survey for the Arkansas study area would have taken as long as the grid sampling. In addition, every polygon would then need to be populated with an estimated value for each of the soil properties. Consequently, a different approach was taken in this study to identify the relationship of soil properties to future yield performance.

The primary purpose of this study was to interpolate soil property data from georeferenced grid points and evaluate its spatial distribution. Another purpose is to assess the individual soil properties and their spatial variability.

USA Study Area

Arkansas is in the south-central part of the conterminous United States. Lonoke County is located in east central Arkansas and is east of Little Rock. The study area is on the Joe Bryant Jr. property near the town of Allport, Arkansas. The latitude of Allport is 34 ∫ 32'53" North and the longitude is 91 ∫ 45'20" West.

Materials and Methods

More than 200 points were inventoried on two fields, each approximately 16 ha, near Allport during March 23 to 25, 1998.

Field 1 is located about 1.6 km north-northwest of Allport, Arkansas (Figure 2). Ten tiers and ten rows were laid out for inventory approximating an aligned grid (Figure 3). The grid matrix for inventorying the points was 41 meters by 41 meters with all grid points offset by 15 meters from the field boundaries. Distances between grid points were approximated by pacing. After the flags were positioned at each point, Global Positioning System (GPS) coordinates were recorded.

Field 2 is located on the northeast edge of Allport, Arkansas. Ten tiers and eleven rows were laid out for inventory in Field 2. The approximate grid matrix for inventorying the points was 41 meters by 36 meters.

An individual field sheet was used to document soil properties at each site. Nine soil and site properties were documented on Field 1 and ten properties were documented on Field 2.

The soil and site property attributes were keyed into Excel software at the conclusion of the field inventory for integration into ArcView 3.0a presentations. The results of the interpolated data were presented to members of the Arkansas Land and Farm Development Corporation (ALFDC) and the UAPB in Little Rock on March 26, 1998.

The precise geographic location of every sample point was recorded in the field using a GPS. The receiver, a Rockwell PLGR, recorded the location of each site and the perimeter of each field to an accuracy level of ±3 meters (Figure 4). It was the accurate placement of each point, as well as the soil sampling data, that allowed other computer software to accurately model the physical characteristics of the fields. Every sample site was also flagged to allow for soil fertility testing to be done at the same site by the Cooperative Extension Service. It is anticipated that yield data will also be collected for the two fields using GPS technology giving an accurate surface map of crop yields. By putting together the three sources of field data (soil physical data, soil fertility data, and yield data) in a Geographic Information System (GIS) it will be possible to study in depth the relationships between the three parameters.

ArcView 3.0a Spatial Analyst software was used to generate interpolated surface maps based on point data. The ArcView algorithm used to interpolate point data for each surface map was the ësplineí option that smoothes data points into a polygon-like configuration.

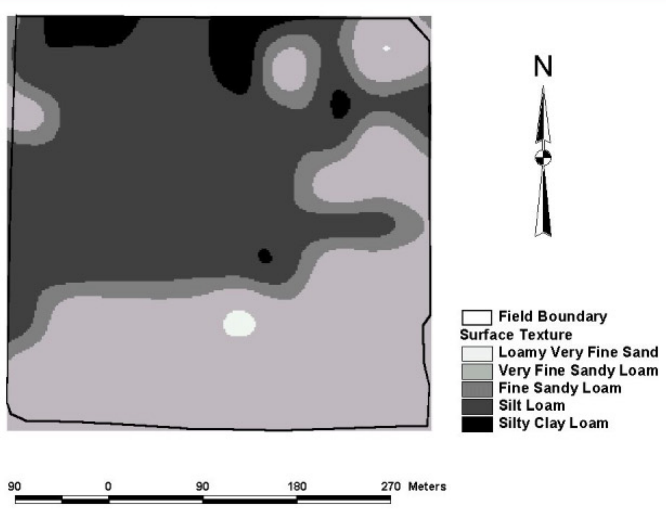

Figure 5. Field 1 surface texture interpolated from point data.

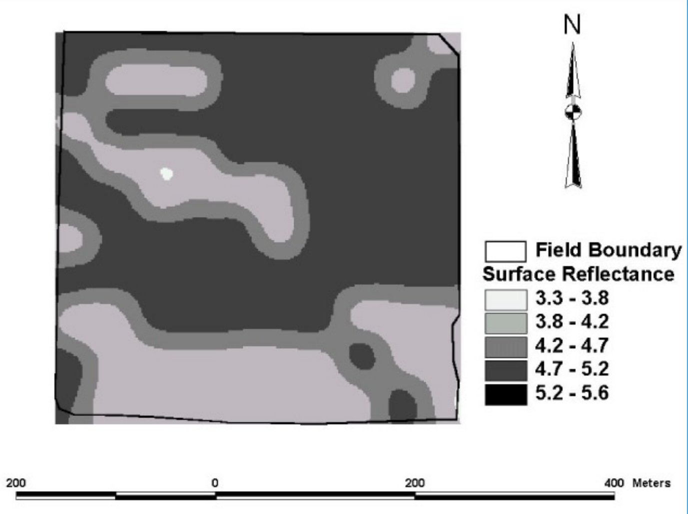

Figure 6. Surface reflectance interpolation map for Field 1.

Results

The visual representation of interpolated soil properties using ArcView software presents an interpolated surface map from grid points. The interpolated results of the ten measured or estimated soil properties are presented below.

Surface Soil Thickness

The soil surface thickness was measured to the nearest 1 cm with a tape measure. The mean soil thickness in Field 1 is 12 cm while it is 10 cm at Field 2. The range in surface thickness is similar (10 to 20 cm versus 3 to 20 cm). The thickness is slightly less variable in Field 1 as indicated by its standard deviation (2.6 versus 3.4 cm). This infers that the surface thickness on both fields is both consistent and predictable.

Surface Soil Texture Class

Surface soil (topsoil) texture class was estimated using USDA-NRCS standards that involved squeezing the soil mass between the thumb and forefinger into a ribbon (Soil Survey Staff, 1993). The longer the ribbon holds until breaking, the more clay content the soil contains. Skilled scientists can approximate the true class in the field without laboratory verification. The surface texture class in Field 1 included loamy very fine sand, very fine sandy loam, fine sandy loam, silt loam, or silty clay loam (Figure 5). The texture in Field 2 is similar except that a loam texture class is also identified. The surface soil at Field 1 contains more silt than Field 2 as inferred by the difference in standard deviations (3.2 versus 2.8).

Surface Infiltration Rate Class

Two surface infiltration rate classes (high and low) were defined prior to the inventory in the study area. Class 2, or high infiltration, was documented where no traffic pan was found at a point and Class 3, or low infiltration, was where a traffic pan was identified at a point. The surface infiltration rate is nearly identical in the study area. High subsoil clay and traffic pans limit the infiltration rate. The mean of the two fields were 2.7 and 2.6, respectively, which suggests that traffic pans occupy more than half of the area of each field.

Surface Reflectance Value (Albedo)

Moist surface color value, sometimes called reflectance or albedo, were collected at each grid point using a Munsell color notation book (Munsell Staff, 1992). The mean surface value in Field 1 is higher than in Field 2 (4.6 versus 3.9). The interpolated surface reflectance value of Field 1 is shown in Figure 6. While the range and standard deviation in the surface reflectance value are similar in the two fields, the lower mean value in Field 2 infers more organic matter, thus less reflectance of sunlight. Moreover, it is conjectured that Field 1 will yield higher than Field 2 on the basis of this property.

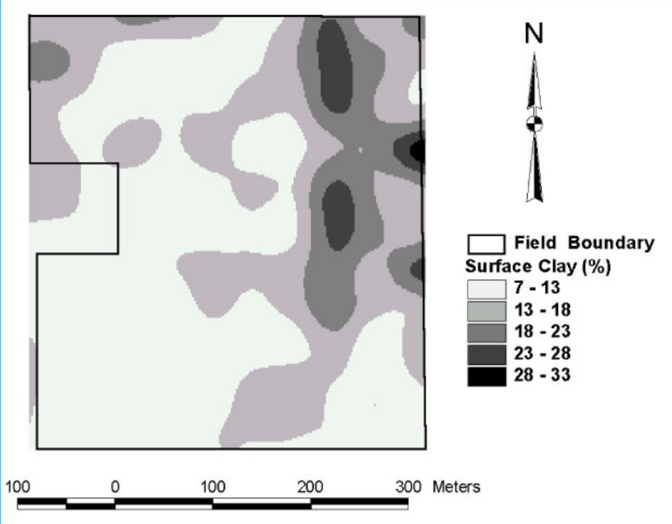

Figure 7. Surface clay content for Field 2.

Depth to Mottles (Redoximorphic Features)

Iron compounds in a soil can display a variegation of color depending on whether it is in a reduced state or in an oxidized state. These genetic tracks indicate seasonal high water table in nature soil ecosystems. The depths of these genetic tracks were measured in the field to the nearest 1 cm. Laser leveling to approximate a flat landscape for agricultural crops and the subsequent formation of traffic pans have induced iron depletions and/or redox concentrations in both fields. Field 1 averaged slightly less in depth to mottles (9.4 to 10.9 cm). Field 1 has a narrower range in depth to mottles than Field 2 (3 to 20 cm versus 1 to 60 cm). Therefore, its standard deviation is less (3.9 versus 6.4 cm).

Surface Clay Content

In most cases, field estimates of clay content approximate laboratory results to within two percent clay. Field 1 averages 15.9 percent estimated clay in the topsoil while Field 2 averages 14.7 percent (Figure 7). The minimum, maximum, and standard deviation values for both fields are nearly identical. Because of the consistent surface clay content among grid points in both fields, it is conjectured that any variation in soybean yield will not be related to this soil property.

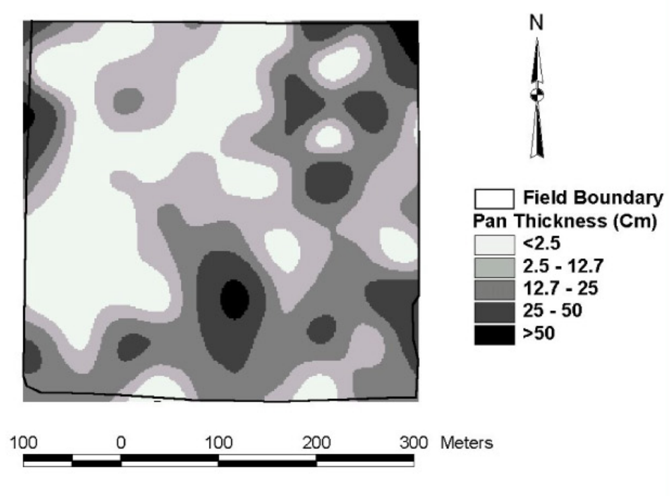

Figure 8. The interpolated pan thickness for Field 1.

Presence and Thickness of Traffic Pan

The presence and thickness of a traffic pan was documented at each point on both fields in the study area. However, the expression or hardness of the pan was not documented because of the highly temporal nature of this property. For instance, a soil with a traffic pan can be identified throughout the year but the traffic pan becomes more expressed as the soil dries out. Field 1 has ten percent more points with a traffic pan than in Field 2 (70 percent versus 60 percent). The range in thickness of the traffic pan is similar in both fields; 0 to 61 cm in Field 1 and 0 to 66 cm in Field 2. The mean thickness of the traffic pan is 14.0 cm in Field 1 and 11.7 cm in Field 2. The standard deviation of the pan thickness approximates the mean pan thickness value in both fields. This infers that the thickness of a traffic pan cannot be modeled solely on the basis of its presence. Pan thickness must be measured to generate an interpolated surface map within a specific field (Figure 8).

Natural Soil Drainage Class

Despite historic modification of the soils in the study area, the natural soil drainage class could be identified at each point in both fields. This was accomplished by examining the Munsell color notations of the subsoil beneath the mottled traffic pan. Many moderately well drained points exhibiting iron depletions and/or redox concentrations at 10 to 15 cm (4 to 6 inches) were mottle-free beneath the pan to a depth of 76 cm (30 inches). Though their configurations are different across the landscape, Field 1 and Field 2 are nearly identical in their range in natural soil drainage and the standard deviation among the points in the field. However, Field 1 has 10 percent more points with better drained soils.

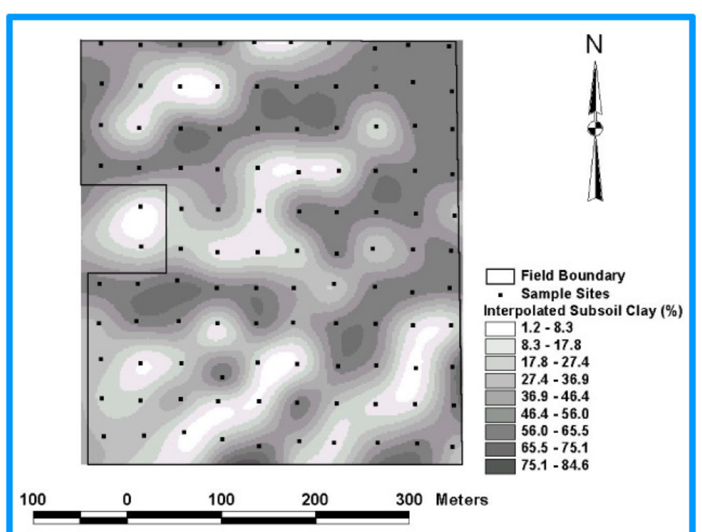

Figure 9. Interpolated subsoil clay content for Field 2 based on 108 sample points.

Runoff Hydrology

Both fields in the study area are similar in their runoff hydrology because they are leveled using laser technology. In other words, laser leveling reduced the significance of this site feature. The results of the analysis of this property are that 20 percent of the grid points in Field 1 have micro-depressions that pond water while 30 percent of the grid points in Field 2 have micro-depressions that pond water.

Maximum Subsoil Clay

In an attempt to address the question of sample-point intensity, the maximum clay content in the subsoil was estimated at all the grid sample points in Field 2. Maximum clay content in the subsoil is the most variable feature of all the soil properties examined during this study. In some cases, the difference in subsoil clay is 60 percent between two grid sampling points. After data for maximum subsoil clay content were collected, it was then interpolated using ArcView Spatial Analyst software (Figure 9).

The grid sample points were then reduced from 108 to 54 by selecting every other point. This resulted in a nonaligned grid matrix. These points were again interpolated using ArcView software (Figure 10). The general distribution of the interpolated maximum subsoil clay content in Figure 10 is similar to that in Figure 9. Therefore, it is possible for some soil properties that a grid matrix with sample points spaced 82 meters by 36 meters apart would be almost as precise as a grid matrix with sample points spaced 41 meters by 36 meters apart.

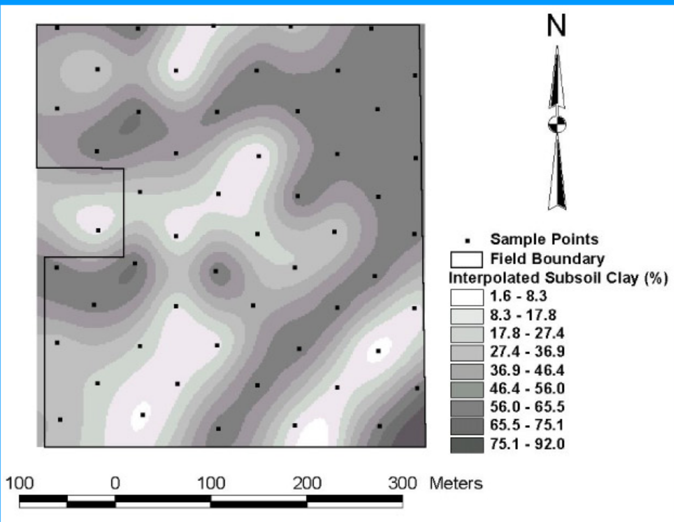

Figure 10. Interpolated subsoil clay content for Field 2 based on 54 sample points.

Conclusions and Discussion

The electronic process of creating surface maps based on soil properties parallels the process of generating surface maps for chemical properties in the SSM research arena. While maps displaying chemical data require laboratory analysis, the soil properties in this study can be either measured or estimated with a high degree of accuracy in the field.

The grid sample point inventory and analysis process used in the study area could be replicated for any SSM project in the world. It is further conjectured that at least one of the physical soil properties in the two 16-ha fields may align with yield data. If yield variability in the study area can be attributed to one or more management induced soil properties, then management solutions can be targeted to maximize yields.

The soils data interpolated from point data in this study are only a start of the support that will be offered by the Soils Deputy area in USDA-NRCS. Additional support in reviewing the fertility data collected by the Cooperative Extension Service in Arkansas will be provided. Furthermore, digital files for this study have been posted onto an ftp server (ftp.nssc.nrcs.usda.gov/incoming).

Low tech solutions do not necessarily need to involve sophisticated software used in this project. A cartographer with a good understanding of soils and distribution techniques could approximate the same map as presented in Figure 7.

Acknowledgments

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